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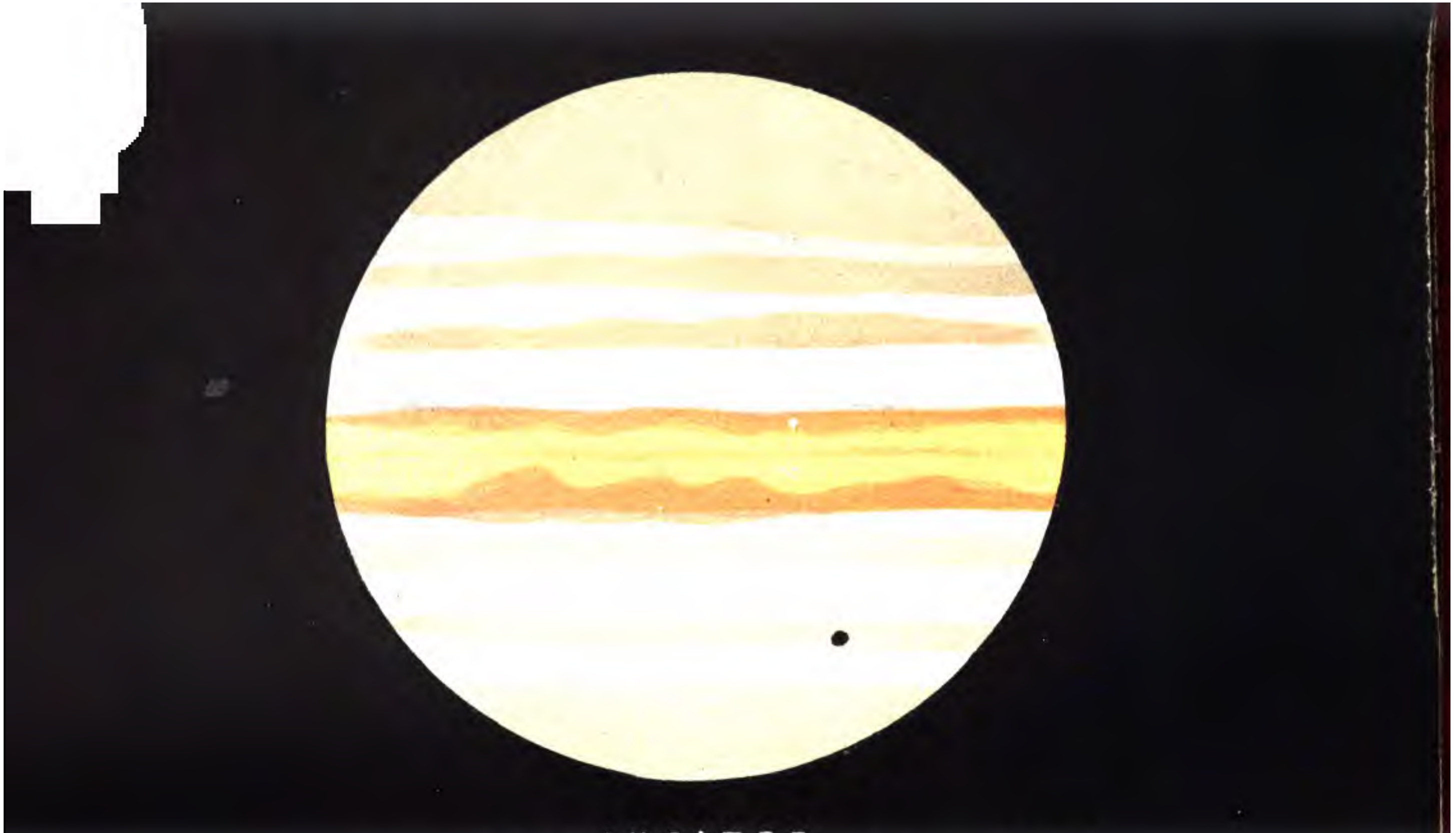
THE

PLURALITY OF WORLDS.

'Lo, these are but a portion of His ways; they utter but a whisper of His glory.' JOB xxvi. 14.



JUPITER.

as seen on Jan^y^ 31st 1870 9.30 P M by J Browning F.R.A.S.

OTHER WORLDS THAN OURS:

THE PLURALITY OF WORLDS
STUDIED UNDER THE LIGHT OF RECENT
SCIENTIFIC RESEARCHES.

BY

RICHARD A. PROCTOR

AUTHOR OF 'THE ORBS AROUND US' 'THE SUN' 'SATURN AND ITS SYSTEM
'ESSAYS ON ASTRONOMY' 'THE UNIVERSE' 'A NEW STAR ATLAS' ETC.

'Not to this evanescent speck of earth
Poorly confined—the radiant tracts on high
Are our exalted range; intent to gaze
Creation through, and from that full complex
Of never-ending wonders, to conceive
Of the SOLE BEING right.—THOMSON.

FIFTH EDITION.

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FROM THE

PREFACE TO THE FOURTH EDITION.

THIS EDITION has been carefully revised, and in many important respects modified.

Several passages relating to questions which were under controversy when the earlier editions appeared have been removed,—those questions having been decided by new evidence, in the sense advocated in the original text.

I have also omitted several passages from the last chapter, as expressing a more confident opinion about matters connected with the supervision and control of the universe than I at present entertain.

RICHARD A. PROCTOR.

FROM THE

PREFACE TO THE SECOND EDITION.

AMONG the additions which have been made to the matter contained in a former edition are two which require some notice.

The first consists of new evidence against the theory that the cloud-belts of Jupiter and Saturn are raised by the sun's heat. I find it difficult to conceive how this evidence can be interpreted otherwise than by the theory that the belts of the giant planets are generated, maintained, and modified by forces inherent in those planets, and not by any action exerted from without.

The second is the matter contained in pp. 264, 265, 274–279, and illustrated by the large plate facing p. 275. Rightly understood, the evidence there presented is conclusive in favour of the two theses, that—

1. *Within the limits which include the stars visible to the naked eye there are laws of aggregation and segregation which the theories hitherto accepted respecting the fixed stars wholly fail to account for.*

2. *The Milky Way is not, as has been so long supposed, a stratum of stars of all orders extending to distances very far exceeding, relatively as well as positively, the distances of the lucid stars,—but is a stream of small stars, amidst which many of the lucid stars are immersed.* These points seem to be as completely demonstrated by the evidence adduced as relations of the sort can ever be.

RICHARD A. PROCTOR.

LONDON: *October*, 1870.

EXTRACTS FROM THE

PREFACE TO THE FIRST EDITION.

On many of the subjects dealt with in this work, I have propounded views which differ from those usually accepted. Each of the new views here presented has been the result of a careful study of the subject dealt with, and I have searched as anxiously for considerations opposed to any novel theory, as for arguments in its favour.

My theory respecting the sidereal system has been based on the signs of systematic aggregation among the lucid stars, and of a more intimate association of those stars with the Milky Way than could be expected were Sir William Herschel's fundamental theory correct.

The theory brought forward in the chapter on Meteors and Comets is not altogether new. The general idea on which it is grounded has been dealt with by Mayer and Thomson. That idea, however, presented itself independently to my mind when I was writing my treatise on Saturn. The line of reasoning is wholly new, I believe, by which I have endeavoured to show that those peculiarities of the solar system which have hitherto been regarded as affording the strongest objection to the hypothesis of development, may be regarded as in reality the direct result of the processes by which the solar system has reached its present condition. In the preface to my treatise on Saturn I touched on the possibility that some such explanation of those peculiarities might be found, remarking that in the rings of Saturn astronomers may one day recognise the action of the processes by which the solar system has attained its present state.

RICHARD A. PROCTOR.

LONDON: *May*, 1870.

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OTHER WORLDS THAN OURS.

INTRODUCTION.

Astronomy and Geology owe much of their charm to the fact that they suggest thoughts of other forms of life than those with which we are familiar. Geology teaches us of days when this earth was peopled with strange creatures such as now are not found upon its surface. We turn our thoughts to the epochs when those monsters throve and multiplied, and picture to ourselves the appearance which our earth then presented. Strange forms of vegetation clothe the scene which the mind's eye dwells upon. The air is heavier laden with moisture to nourish the abundant flora; hideous reptiles crawl over their slimy domain, battling with each other or with the denizens of the forest; huge bat-like creatures sweep through the dusky twilight which constituted the primeval day; weird monsters pursue their prey amid the ocean depths: and we forget, as we dwell upon the strange forms which existed in those long past ages, that the scene now presented by the earth is no less wonderful, and that the records of our time may perhaps seem one day as perplexing as we now find those of the geological eras.

Astronomy has a kindred charm. We cannot indeed examine the actual substance of living creatures existing upon other celestial bodies; we cannot picture to ourselves their appearance or qualities; and only in a few instances can we even form any conception of the conditions under which they live. But we see proofs on all sides that, besides the world on which we live, other worlds exist as well cared for and as nobly planned. Nay, we see globes by the side of which our earth would seem but as a tiny speck; we trace these globes as they sweep with stately motion on their appointed courses; we watch the return of day on the broad expanse of their surface; and we see systems of satellites which are suspended as lights for their nocturnal skies. We further find that our sun is matched by a thousand thousand suns amid the immeasurable depths of space; and the mind's eye pictures other worlds like those which course around the sun, travelling in stately orbits around his fellow luminaries.

Long, however, before the wonders of modern astronomy had been revealed to us, men of inquiring minds seem to have been led, as by an irresistible instinct, to examine into the resemblance which may exist between our world and other worlds surrounding it on every side. It has not been the mere fanciful theoriser who has discussed such questions, but men of the highest eminence in science. In long past ages Anaximander and Pythagoras studied the subject of other worlds than ours; later, such men as Huyghens, Galileo, and Newton have dwelt upon the same interesting theme; while, in our own day, Whewell and Brewster have employed their scientific and dialectic skill in defending rival theories upon the subject.

Undoubtedly, a large share of the interest with which the question of other worlds than ours has been regarded is due to the fact that, as the science of astronomy has progressed, the subject has continually presented itself under new aspects. The question, in fact, is one of those which are ever new and ever old. It has all the charm belonging to subjects which men in all ages have delighted to discuss, while it is associated in the most intimate manner with the progress of modern scientific research. The discoveries which are made by astronomers acquire a new interest when they are associated with the subject of life in other worlds. The interest with which the public regard many of those discoveries may, indeed, be said to depend wholly on their bearing upon this subject.

We stand in a position much more favourable for the formation of just views on the subject of life in other worlds than that from which men surveyed the planetary and stellar systems thirty or forty years since. Never, since men first explored the celestial depths, has a series of more startling discoveries rewarded the labours of astronomers and physicists than during the past few years. Unhoped-for revelations have been made on every side. Analogies the most interesting have brought the distant orbs of heaven into close relationship with our own earth or with the central luminary of the planetary scheme. And a lesson has been taught us which bears even more significantly on our views respecting the existence of other worlds: we have learned to recognise within the solar system, and within the wondrous galaxy of which our sun is a constituent orb, a variety of structure and a complexity of detail, of which but a few years ago astronomers had formed but the most inadequate conceptions.

My object, then, in the pages which follow, is not solely to establish the thesis that there are other worlds than ours, but to present, in a new and I hope interesting light, the marvellous discoveries which have rewarded recent scientific researches. Judged merely according to their direct significance, these discoveries are full of interest. But it is when we consider them in their relation to the existence of other worlds, when we attempt to form a conception of the immense varieties of the forms of life corresponding to the innumerable varieties of cosmical structure disclosed by modern researches, that we recognise their full significance. Although the growth of our knowledge is ever accompanied by a proportional growth of our estimate of the unknown, we seem already entitled to say that we have

> Come on that which is, and caught
> The deep pulsations of the world,
> Æonian music, measuring out
> The steps of time.

CHAPTER I.

WHAT OUR EARTH TEACHES US.

BEFORE proceeding to consider the various circumstances under which the worlds or systems which surround us appear to subsist, it may be well to inquire how far we have reason to conclude, from the consideration of our own earth, that other orbs in space support life.

It would not be just to argue directly from the fact that the earth is inhabited to the conclusion that the other planets are inhabited also, nor thence to the conclusion that other stars have, like our sun, their attendant worlds, peopled with various forms of life. An analogy founded on a single instance has no logical force. And it is doubtful whether we have not, in the moon, an instance which would as effectually serve to support a directly opposite conclusion. It seems all but certain, as we shall presently have occasion to show, that no part of the moon's globe is inhabited by living creatures. Certainly she is inhabited by none which bear the least resemblance to those existing on our earth. Thus it might fairly be urged, that since one of the two orbs respecting which we know most appears to be uninhabited, there remains no probable argument in favour of the view that other orbs besides our earth are the abode of living creatures.

Yet the earth in reality supplies an argument of great force, when we consider the evidence she presents in another light. The mere fact that this world is inhabited is, as we have seen, little; but we shall find that the way in which life is distributed over the earth's surface is full of significance.

If we range over the earth, from the Arctic regions to the torrid zone, we find that none of the peculiarities which mark the several regions of our globe suffice to banish life from its surface. In the bitter cold within the Arctic circles, with their strange alternations of long summer days and long winter nights, their frozen seas, perennial ice, and scanty vegetation, life flourishes in a hundred various forms. On the other hand, the torrid zone, with its blazing heat, its long-continued droughts, its strange absence of true seasonal changes, and its trying alternations of oppressive calms and fiercely raging hurricanes, nourishes even more numerous and more various forms of life than either of the great temperate zones. Around mountain summits as in the depths of the most secluded valleys, in mid-ocean as in the arid desert, in the air as beneath the surface of the earth, we find a myriad forms of life.

But this is far from being all. Various as are the physical habitudes which we encounter as we travel over the surface of our globe, we are able to trace the existence of other varieties even more remarkable. The geologist has been able to turn back a few leaves of the earth's past history, and though the pages have been defaced and mutilated by Time's unsparing hand, he is yet able to read in them of many strange vicissitudes to which the continents and oceans of our globe have been exposed. But, far back as he can trace the earth's history, and already he counts her age by millions of years, he finds no evidence of an epoch when life was absent from her surface. Nay, if he reads aright the mysterious lesson which the blurred letters teach him, he is led to believe that, at the most distant epoch to which his researches have extended, there was the same wonderful variety in the forms of life as at the present day. He can, indeed, find the scattered remains of only a few of those old-world creatures; but he recognises, in those which have been preserved, the clearest evidence that thousands of others must have existed around them. He knows, that of a million creatures now existing, scarcely one will leave to future ages any record of its existence; he sees whole races vanishing from the earth, leaving no trace behind them; and he is thus able to form an estimate of the enormous extent by which the creatures and races of which he can learn *nothing* must have outnumbered those whose scattered remains attest their former existence upon the earth.

Here, then, we have analogies which there is no mistaking. We see, that not only is Nature careful to fill all available space with living forms, but that no time over which our researches extend has found her less prodigal of life. We see that, within very wide limits, she has a singular power of adapting living creatures to the circumstances which surround them. Nor is this lesson affected—like the general lesson drawn from the mere fact of the earth's being inhabited—by anything we can learn from the aspect of our satellite. For the arguments against the presence of living creatures on the moon are founded on the evidence we have that the physical habitudes of that orb are outside the limits within which Nature effects the adaptation spoken of.

The moon teaches us, however, that all the celestial bodies are not at all times habitable. The sun also teaches the same lesson. And it is necessary that we should consider how far the evidence presented by our own earth may serve to elucidate this teaching. We shall see that terrestrial analogies afford a very sure guide in the midst of many perplexities presented by the study of the worlds around us.

Let us trace out the various degrees of fitness or unfitness for the support of particular forms of life, which we recognise in various regions of our earth.

Often, where there exists so slight a difference between two regions of the earth that, to ordinary observation, it would appear that the forms of life existing in one should be well adapted to the other also, we yet find that this is not the case. Some minute peculiarity of soil, or climate, or vegetation, will render one region absolutely uninhabitable by a race which lives and thrives in the other. Darwin mentions several instances in which an apparently insignificant change in the circumstances under which a particular race has thriven, and sometimes a change which does not, at first sight, appear to be in the least connected with the well-being of the race, has led to its gradual disappearance. And it seems demonstrated, that even the slow processes of change to which every part of the earth is subjected, would suffice to destroy a number of the races now subsisting on its surface, were the characteristics of those races unalterable. But as the physical habitudes of their abode slowly change, the various races of living creatures slowly change also, so as to adapt themselves continually to the varying circumstances under which they live.

The lesson taught us by this peculiarity is very obvious. On the one hand, we see that it would be by no means sufficient to indicate a general resemblance between the physical habitudes of our earth and those of some far distant planet, in order to prove that that planet is the abode of living creatures resembling those on our own earth. But, on the other hand, we are taught that the existence of differences sufficient to render a distant planet an unsuitable abode for such creatures as we are familiar with, cannot force upon us the conclusion that the planet is uninhabited. On the contrary, the circumstance we have been considering teaches us that such differences as would suffice to banish life of certain kinds are insufficient to banish life of all kinds, or even to render less abundant the forms of life which exist under those changed conditions.

And now we may proceed a step farther. On our earth we find differences of climate and of physical habitudes generally, which are much more important than those hitherto dealt with. We see that not only would certain races perish in the long run, if removed from their own abode to other parts of the earth, but that, in some instances, the process of destruction would be very rapid indeed. If we were to remove the polar bears from their Arctic fastnesses to tropical, or even to the warmer parts of temperate regions, a very few years would see the end of the whole race. The races inhabiting steppes and prairies would quickly perish if removed to mountain regions. Those accustomed to a moisture-laden air and abundant vegetation would not survive long if removed to the desert.

In some races, indeed, we find a power of enduring such changes which very far exceeds that possessed by other races. Those creatures, for example, which man has domesticated seem capable of enduring a variety of climate or of circumstances, which would destroy the seemingly more vigorous races not yet subdued to the yoke of man.*

---

* Humboldt tells us, that 'the pliability of the organisation of those animals which man has subjected to his sway, enables horses, cows, and other species of European origin, to lead for a time an amphibious life, surrounded by crocodiles, water-serpents, and manatees. When the rivers return again to their beds, the horses roam in the Savannah, which is then spread over with a fine odoriferous grass; and enjoy, as in their native climate, the renewed vegetation of spring.'

Even man himself, however, though he possesses in an unrivalled degree the power of enduring in safety the most complete change of climate, scene, and circumstances, is yet limited, in a certain sense, in his power of migration. The Englishman, for example, can endure the fiercest heat of the tropics or the bitterest cold of Arctic and Antarctic regions. But he cannot safely attempt to found true colonies in every part of the earth's surface. Our countrymen in India must send their children to be reared in England, if they wish them to grow up strong and vigorous. There can be little doubt that if a thousand men and women from this country were to settle in certain parts of India (not at any time intermarrying with the natives), the colony would disappear within a couple of centuries.

Here we have a second degree of unfitness, according to which certain countries would quickly become depopulated, if supplied with inhabitants from certain other countries. We are taught the same lesson as before, but in a more striking manner. We see that differences exist within the confines of our own earth, which render particular countries absolutely uninhabitable by particular races, insomuch that though the individual might survive, the race itself would quickly perish. And we see, on the other hand, that these countries are not uninhabited, or even less fully peopled with living creatures, than seemingly more fortunate abodes.

Now, if some impassable barrier prevented the inhabitants of one country from visiting others, while yet it was possible to learn something of the conditions prevailing in other regions, how readily the conclusion might be reached, that some at least of those inaccessible regions must be wholly uninhabited, simply because their physical habitudes appeared unsuited to the wants of the only creatures with which the observer was familiar. Who would believe, for example, that men can live, and not only live but thrive and multiply, in the frost-bound regions within the Arctic Circle, if travellers had not visited the Esquimaux races, and witnessed the conditions under which they subsist? Again, if we knew nothing of India, and some one pictured to us the intense heat of the Indian sun, the strange alternations of weather which replace to the Indian the seasonal changes we are familiar with, and all the other circumstances which render tropical regions so different from our English home, who could believe that, amidst those seemingly unendurable vicissitudes, there are races of men that thrive and multiply, even as our people in their temperate zone? *

Therefore, in examining the circumstances of other

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* Perhaps the most striking instance of man's power of living under circumstances seemingly the most unfavourable, is to be found in the fact, that though the strongest traveller is affected seriously by the rarity of the air at great elevations, yet races of men live and thrive in Potosi, Bogotà, and Quito, and—to use the words of a modern writer—that bull-fights should be possible at an elevation at which Saussure hardly had energy to consult his instruments, and where even his guides fainted as they tried to dig a small hole in the snow.

worlds than ours, it will not be sufficient to prove that certain orbs would obviously not be habitable by the races subsisting on the earth, in order to enforce the conclusion that no living creatures subsist at all upon their surface.

Yet another step farther, however. There are regions of the earth where the members of races belonging to other regions *quickly* perish. The air of our own England is death to many creatures. And, indeed, there is not a spot in the whole world which would not be fatal in a brief space to many animals and plants belonging to other regions. Yet each spot, though thus fatal to certain races, is inhabited by numbers of others, which live and thrive upon its surface.

Here, then, is our third lesson. We are taught by the analogy of our earth, that it is not even sufficient to show that a planet would be an abode quickly fatal to all the living creatures subsisting on our globe, to prove that it is therefore uninhabited.

But we have yet a stronger argument to touch on. There are regions of our earth to which creatures from other regions cannot be removed without being *immediately* killed. The warm-blooded animal perishes, if placed for a brief space under water. The fish perishes if placed for a brief space on the earth.* What could be more wonderful to us, were we not familiar with the fact, than that there are living creatures within the depths of that ocean, beneath whose surface we ourselves, and the land creatures we are familiar with, cannot remain alive many minutes? If fishes could reason, how could they believe that creatures can live in comfort in that element which is death to them? Yet land and river and sea are alike peopled with living creatures, each race as well adapted as its fellows to the circumstances in which it is placed.

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* Perhaps the fact that there are certain kinds of fish which can not only live out of water, but can travel across the dry land, or climb trees, affords an even more striking instance of Nature's power of adapting creatures to the circumstances which surround them.

We are taught, then, yet another lesson. We see that even though we could prove that every living creature on this earth would at once perish if removed to another orb, yet we cannot thence conclude that that orb is uninhabited. On the contrary, the lesson conveyed by our earth's analogy leads to the conclusion that many worlds may exist, abundantly supplied with living creatures of many different species, where yet every form of life upon our earth—bird, beast, or fish, reptile, insect, or animalcule—would perish in a few moments.*

There remains yet a last lesson to be drawn from terrestrial analogies. On the earth there are regions where no form of life exists or can exist. Within the flaming crater of the volcano, or in the frozen heart of the iceberg, no living creature has its being. Yet even here Nature proves to us that the great end and aim of all her working is to afford scope and room for new forms of life, or to supply the wants of those which already exist. The volcano will die out, and the scene of its activity will one day become the abode of myriads of living creatures who would have perished in a moment in its consuming fires. The iceberg will melt, and its substance will once again be peopled with busy life. But this is little. It is the work of which volcano and iceberg are the signs, which most significantly teaches us what is Nature's real aim. The volcano is the index of those busy subterranean forces which are remodelling the earth's frame, slowly changing the level of the land, making continents of oceans and oceans of continents, preserving and vivifying all things, while all things seem to suffer a gradual destruction. The iceberg, too, has its work in remodelling and fashioning the surface of new continents. It also acts an important part in the formation and maintenance of the system of oceanic circulation on which the welfare of land creatures and water creatures so largely depends. And so of a multitude of other phenomena, which appear at first sight significant rather of the destructive than of the life-preserving character of Nature. The tornado and the thunder-storm, the earthquake and the volcano—nay, even the dreaded returns of plague and pestilence, have each a more powerful influence by far towards the preservation than they have towards the destruction of life.

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* I might add to the instances here cited, many others which seem even more striking. We know that in strong acids which would instantly kill bird, beast, fish, or insect placed within them, there exist and thrive minute creatures, adapted by Nature to the strange conditions in which they are placed. Even in the bowels of the earth and in the very neighbourhood of active volcanoes, we find the Volcano-fish existing in such countless thousands, that when they are from time to time vomited forth by the erupting mountain, their bodies are strewn over enormous regions, and as they putrefy beneath the sun's rays, spread pestilence and disease among the inhabitants of the neighbouring districts.

We see, then, that even if we could prove that an orb in space is so circumstanced that no life could by any possibility exist upon its surface; if it were the scene of a fierce and destructive turmoil, one moment of which would suffice to destroy every living creature now existing upon the earth; if its whole mass were heated to a degree a thousandfold more intense than that of the fiercest heat we know of; if its surface were bound in a cold compared with which our Arctic frosts would seem like tropical heat; or even if the most rapid alternation of these extremes took place upon and within it; even then we could not conclude that it has not been in long-past ages, or will not be in ages yet to come, the abode of life.

Lastly, even when we can safely assert of any celestial object, that neither now, nor at any past or future time, could it serve as the abode of living creatures, we are led by terrestrial analogies to the conclusion that it yet supports life in other ways. So that these very orbs, of which it seems safest to assert that they are, have ever been, and must ever remain uninhabited, speak to us, no less strongly than those which appear best suited for habitation, of the existence of other worlds than ours.

CHAPTER II.

WHAT WE LEARN FROM THE SUN.

I DO not propose to dwell in this chapter on the views which have been propounded respecting the sun's habitability. It is not merely that I regard those views as too fanciful to find place in a serious consideration of the subject I am dealing with, nor that the progress of recent observation has rendered them utterly untenable, but that, in fact, they do not belong to what the sun teaches us. I wish to consider only the real evidence which the sun affords respecting the scheme of creation, to dwell upon the purposes which he subserves in the economy of the solar system, and thence to deduce a lesson respecting those other suns scattered through space, which we call the fixed stars.

Let us first endeavour to form adequate conceptions respecting the dimensions of the great central luminary of the solar system.

Let the reader consider a terrestrial globe three inches in diameter, and search out on that globe the tiny triangular speck which represents Great Britain. Then let him endeavour to picture the town in which he lives as represented by the minutest pin-mark that could possibly be made upon this speck. He will then have formed some conception, though but an inadequate one, of the enormous dimensions of the earth's globe, compared with the scene in which his daily life is cast. Now, on the same scale, the sun would be represented by a globe about twice the height of an ordinary sitting-room. A room about twenty-six feet in length, and height, and breadth, would be required to contain the representation of the sun's globe on this scale, while the globe representing the earth could be placed in a moderately large goblet.

Such is the body which sways the motions of the solar system. The largest of his family, the giant Jupiter, though of dimensions which dwarf those of the earth or Venus almost to nothingness, would yet only be represented by a thirty-two inch globe, on the scale which gives to the sun the enormous volume I have spoken of. Saturn would have a diameter of about twenty-eight inches, his ring measuring about five feet in its extreme span. Uranus and Neptune would be little more than a foot in diameter, and all the minor planets would be less than the three-inch earth. It will thus be seen that the sun is a worthy centre of the great scheme he sways, even when we merely regard his dimensions.

The sun outweighs fully 740 times the combined mass of all the planets which circle around him, so that when we regard the energy of his attraction, we still find him a worthy ruler of the planetary scheme.

But after all, the enormous volume and mass of the sun form the least important of his characteristics as the ruling body of the solar system. It is when we contemplate him as the source whence the supplies of heat and light required by our own world and the other planets are plentifully bestowed, that we see what is his chief office in the economy of the planetary scheme.

Properly speaking, the physical constitution of the sun only requires to be dealt with in such a work as the present in so far as it is directly associated with the sun's action upon the worlds around him, or as it may bear on the question of the constitution of those worlds. But the subject is so interesting, and it would indeed be so difficult to draw a line of demarcation between the facts which bear upon the question of other worlds and those which do not, that I may be permitted to enter at some length into a consideration of the solar orb, as modern physical discoveries present it to our contemplation.

The study of solar physics may be said to have commenced with the discovery of the sun-spots, about 267 years ago. These spots were presently found to traverse the solar disc in such a way as to indicate that the sun turns upon an axis once in about twenty-six days. Nor will this rotation appear slow, when we remember that it implies a motion of the equatorial parts of the sun's surface at a rate exceeding some seventy times the motion of our swiftest express trains.

Next came the discovery that the solar spots are not surface stains, but deep cavities in the solar substance. The changes of appearance presented by the spots as they traverse the solar disc, led Dr. Wilson to form this theory so far back as 1779; but, strangely enough, it is only in comparatively recent times that the hypothesis has been finally established. For even within the last ten years a theory was put forward which accounted satisfactorily for most of the changes of appearance observed in the spots, by supposing them to be due to solar clouds hanging suspended at a considerable elevation above the true photosphere.

Sir William Herschel, reasoning from terrestrial analogies, was led to look on the spot-cavities as apertures through a double layer of clouds. He argued, that were the solar photosphere of any other nature, it would be past comprehension that vast openings should form in it, to remain open for months before they close up again. Whether we consider the enormous rapidity with which the spots form and with which their figure changes, or the length of time that many of them remain visible, we find ourselves alike perplexed, unless we assume that the solar photosphere resembles a bed of clouds. Through a stratum of terrestrial clouds openings may be formed by atmospheric disturbances, but while undisturbed the clouds will retain any form once impressed upon them, for a length of time corresponding to the weeks and months during which the solar spots endure.

And because the solar spots present two distinct varieties of light, the faint penumbra and the dark umbra or nucleus, Herschel saw the necessity of assuming that there are two beds of clouds, the outer self-luminous and constituting the true solar photosphere, the inner reflecting the light received from the outer layer, and so shielding the real surface of the sun from the intense light and heat which it would otherwise receive.

But while recent discoveries have confirmed Sir William Herschel's theory about the solar cloud-envelopes, they have by no means given countenance to his view that the body of the sun may possibly be cool. The darkness of the nucleus of a spot is found, on the contrary, to give proof that in that neighbourhood the sun is hotter, because it parts less readily with its heat. We shall see presently how this is. Meantime let it be noticed in passing, that a close scrutiny of large solar spots has revealed the existence of an intensely black spot in the midst of the umbra. This black spot must be regarded as the true nucleus.

The circumstance that the spots appear only on two bands of the sun's globe, corresponding to the sub-tropical zones on our own earth, led the younger Herschel to conclusions as important as those which his father had formed. He reasoned, like his father, from terrestrial analogies. On our own earth the sub-tropical zones are the regions where the great cyclonic storms have their birth, and rage with their chief fury. Here, therefore, we have the analogue of the solar spots, if only we can show reason for believing that upon the result, and upon other discoveries which have been made by observers who have taken up the same work.

Schwabe found that in the course of about eleven years the solar spots pass through a complete cycle of changes. They become gradually more and more numerous up to a certain maximum, and then as gradually diminish. At length the sun's face becomes not only clear of spots, but a certain well-marked darkening around the border of his disc disappears altogether for a brief season. At this time the sun presents a perfectly uniform disc. Then gradually the spots return, become more and more numerous, and so the cycle of changes is run through again.

The astronomers who have watched the sun from the Kew observatory have found that the process of change by which the spots sweep in a sort of 'wave of increase' over the solar disc is marked by several minor variations. As the surface of a great sea-wave will be traversed by small ripples, so the gradual increase and diminution in the number of the solar spots is characterised by minor gradations of change, which are sufficiently well marked to be distinctly cognisable.

There seems every reason for believing that the periodic changes thus noticed are due to the influence of the planets upon the solar photosphere, though in what way that influence is exerted is not at present perfectly clear. Some have thought that the mere attraction of the planets tends to produce tides of ome sort in the solar envelopes. Then, since the height of a tide so produced varies as the cube or third power of the distance, it has been thought that a planet when in perihelion would generate a much larger solar tide than when in aphelion. So that, as Jupiter has a period nearly equal to the sun-spot period, it has been supposed that the attractions of this planet are sufficient to account for the great spot-period. Venus, Mercury, the Earth, and Saturn have, in a similar manner, been rendered accountable for the shorter and less distinctly marked periods.

Without denying that the planets may be, and probably are, the bodies to whose influence the solar-spot periods are to be ascribed, I yet venture to express very strong doubts whether the action of Jupiter is so much greater in perihelion than in aphelion as to account for the fact, that whereas at one season the face of the sun shows many spots, at another it is wholly free from them.

However, we are not at present concerned so much with the explanation of facts as with the facts themselves. We have to consider rather what the sun is, and what he does for the solar system, than why these things are so.

Let us note, before passing to other circumstances of interest connected with the sun, that the variable condition of his photosphere must cause him to change in brilliancy as seen from vast distances. If Herr Schwabe, for instance, instead of observing the sun's spots from his watch-tower at Dessau, could have removed himself to a distance so enormous that the sun's disc would have been reduced, even in the most powerful telescope, to a mere point of light, there can be no doubt that the only effect which he would have been able to perceive would have been a gradual increase and diminution of brightness, having a period of about eleven years.

Our sun, therefore, if viewed from the neighbourhood of any of the stars, whence undoubtedly he would simply appear as one among many fixed stars, would be a 'variable,' having a period of about eleven years, and a very limited range of variation. Further, if an observer, viewing the sun from so enormous a distance, had the means of very accurately measuring its light, he would undoubtedly discover that while the chief variation of the sun takes place in a period of about eleven years, its light is subjected to minor variations, having shorter periods.

The discovery that the periodic changes of the sun's appearance are associated with the periodic changes in the character of the earth's magnetism is the next that we have to consider.

It had long been noticed, that during the course of a single day the magnetic needle exhibits a minute change of direction, taking place in an oscillatory manner. And when the character of this vibration came to be carefully examined, it was found to correspond to a sort of effort on the needle's part to turn towards the sun. For example, when the sun is on the magnetic meridian, the needle has its mean position. This happens twice in the day, once when the sun is above the horizon, and once when he is below it. Again, when the sun is midway between these two positions—which also happens twice in the day, the needle has its mean position, because the northern and the southern ends make equal efforts, so to speak, to direct themselves towards the sun. Four times in the day, then, the needle has its mean position, or is directed towards the magnetic meridian. But when the sun is not in one of the four positions considered, that end of the needle which is nearest to him is slightly turned away from its mean position, towards him. The change of position is very minute, and only the exact methods of observation made use of in the present age would have sufficed to reveal it. There it is, however, and this minute and seemingly unimportant peculiarity has been found to be full of meaning.

Had science merely measured this minute variation, the work would have given striking evidence of the exact spirit in which men of our day deal with natural phenomena. But science was to do much more. The variations of this minute variation were to be inquired into; their period was to be searched for; the laws by which they were regulated and by which their period might perhaps itself be rendered variable, were to be examined; and finally, their relation to other natural laws was to be sought after. That science should set herself to an inquiry so delicate and so difficult, in a spirit so exacting, was nothing unusual. It is thus that all the great discoveries of our age have been effected. But it is well that the reader should recognise the careful scrutiny to which natural phenomena have been subjected before the great laws we have to consider were made known. It is thought by many, who have not been at the pains to examine what science is really doing in our day, that the wonders she presents to men's contemplation, the startling revelations which are being made from day to day, are merely dreams and fancies, which replace indeed the dreams and fancies of old times, but have no worthier claims on our belief. Those who carefully examine the history of science will be forced to adopt a very different opinion.

The minute vibrations of the magnetic needle, thus carefully watched—day after day, month after month, year after year—were found to exhibit a yet more minute oscillatory change. They waxed and waned within narrow limits of variation, but yet in a manner there was no mistaking. The period of this oscillatory change was not to be determined, however, by the observations of a few years.* Between the time when the diurnal vibration was least until it had reached its greatest extent, and thence returned to its first value, no less than eleven years elapsed, and a much longer time passed before the periodic character of the change was satisfactorily determined.

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* The reader must not understand that the account here given presents in any sense even a general view of the labours of those who have studied the earth's magnetism. I touch only on those points by which the association between the earth's magnetism and the physical condition of the sun are most clearly indicated; because these points alone bear on the subject of this chapter. How they do so will appear farther on.

The reader will at once see what these observations tend to. The sun-spots vary in frequency within a period of eleven years, and the magnetic diurnal observations vary within a period of the same duration. It might seem fanciful to associate the two periodic series of changes together, and doubtless when the idea first occurred to Sabine, it was not with any great expectation of finding it confirmed, that he examined the evidence bearing on the point. Judging from known facts, we may see reasons for such an expectation in the correspondence of the needle's diurnal vibration, with the sun's apparent motion, and also in the law which associates the annual variations of the magnet's power with the sun's distance. But undoubtedly when the idea occurred to Sabine, it was an exceedingly bold one, and the ridicule with which the first announcement of the supposed law was received, even in scientific circles, suffices to show how unexpected that relation was which is now so thoroughly established. For a careful comparison between the two periods has demonstrated that they agree most perfectly, not merely in length, but maximum for maximum, and minimum for minimum. When the sun-spots are most numerous, then the daily vibration of the magnet is most extensive, while, when the sun's face is clear of spots, the needle vibrates over its smallest diurnal arc.

Then the intensity of the magnetic action has been found to depend upon solar influences. The vibrations by which the needle indicates the progress of those strange disturbances of the terrestrial magnetism which are known as magnetic storms, have been found not merely to be most frequent when the sun's face is most spotted, but to occur simultaneously with the appearance of signs of disturbance in the solar photosphere. For instance, during the autumn of 1859, the eminent solar observer, Carrington, noticed the apparition of a bright spot upon the sun's surface. The light of this spot was so intense, that he imagined the screen which shaded the plate employed to receive the solar image had been broken. By a fortunate coincidence, another observer, Mr. Hodgson, happened to be watching the sun at the same instant, and witnessed the same remarkable appearance. Now it was found that the self-registering magnetic instruments of the Kew observatory had been sharply disturbed at the instant when the bright spot was seen. And afterwards it was learned that the phenomena which indicate the progress of a magnetic storm had been observed in many places. Telegraphic communication was interrupted, and at a station in Norway the telegraphic apparatus was set on fire; auroras appeared both in the northern and southern hemispheres during the night which followed; and the whole frame of the earth seemed to thrill responsively to the disturbance which had affected the great central luminary of the solar system.

The reader will now see why I have discussed relations which hitherto he may perhaps have thought very little connected with my subject. He sees that there is a bond of sympathy between our earth and the sun; that no disturbance can affect the solar photosphere without affecting our earth to a greater or less degree. But if our earth, then also the other planets. Mercury and Venus, so much nearer the sun than we are, surely respond even more swiftly and more distinctly to the solar magnetic influences. But beyond our earth, and beyond the orbit of moonless Mars, the magnetic impulses speed with the velocity of light. The vast globe of Jupiter is thrilled from pole to pole as the magnetic wave rolls in upon it; then Saturn feels the shock, and then the vast distances beyond which lie Uranus and Neptune are swept by the ever-lessening yet ever-widening disturbance-wave. Who shall say what outer planets it then seeks? or who, looking back upon the course over which it has travelled, shall say that planets alone have felt its effects? Meteoric and cometic systems have been visited by the great magnetic wave, and upon the dispersed members of the one and the subtle structure of the other effects even more important may have been produced than those striking phenomena which characterise the progress of terrestrial or planetary magnetic storms.

When we remember that what is true of a relatively great solar disturbance, such as the one witnessed by Messrs. Carrington and Hodgson, is true also (however different in degree) of the magnetic influences which the sun is at every instant exerting, we see that a new and most important bond of union exists between the members of the solar family. The sun not only sways them by the vast attraction of his gravity, not only illumines them, not only warms them, but he pours forth on all his subtle yet powerful magnetic influences. A new analogy between the members of the solar system is thus introduced.

And now we pass on to other discoveries, bearing at once and with equal force upon the relations between the various members of the solar system and upon the position which that system occupies in the universe.

Hitherto we have been considering the teachings of the telescope; we have now to consider what we have learned by means of an instrument of yet higher powers. As I shall have to refer very frequently, throughout this volume, to the teachings of the spectroscope, it will be well that I should briefly describe what it is that this instrument really effects. Were I simply to state the results of its use, without describing its real character, many of my readers would be disposed to believe that astronomers are as credulous as in reality they are exacting and scrupulous, where new facts and observations are in question.

The real end and aim of the telescope, as applied by the astronomer to the examination of the celestial objects, is to gather together the light which streams from each luminous point throughout space. We may regard the space which surrounds us on every side as an ocean without bounds or limits, an ocean across which there are ever sweeping waves of light, either emitted directly from the various bodies subsisting throughout space, or else reflected from their surfaces. Other forms of wave also speed across those limitless depths in all directions; but the light-waves are those which at present concern us. Our earth is as a minute island placed within the ocean of space, and to the shores of this tiny isle the light-waves bear their message from the orbs which lie like other isles amid the fathomless depths around us. With the telescope the astronomer gathers together portions of light-waves which else would have travelled in diverging directions. By thus intensifying their action, he enables the eye to become cognisant of their true nature. Precisely as the narrow channels around our shores cause the tidal wave, which sweeps across the open ocean in almost insensible undulations, to rise and fall through a wide range of variation, so the telescope renders sensible the existence of light-waves which would escape the notice of the unaided eye.

The telescope, then, is essentially a *light-gatherer.*

The spectroscope is used for another purpose. It might be called the *light-sifter.* It is applied by the astronomer to analyse the light which comes to him from beyond the ocean of space, and so to enable him to learn the character of the orbs from which that light proceeds.

The principle of the instrument is simple, though the appliances by which its full powers can alone be educed are somewhat complicated.

A ray of sunlight falling on a prism of glass or crystal does not emerge unchanged in character.

Different portions of the ray are differently bent, so that when they emerge from the prism they no longer travel side by side as before. The violet part of the light is bent most, the red least; the various colours from violet through blue, green, and yellow, to red, being bent gradually less and less.

The prism then *sorts*, or *sifts*, the light-waves.

But we want the means of sifting the light-waves more thoroughly. The reader must bear with me while I describe, as exactly as possible in the brief space available to me, the way in which the first rough work of the prism has been modified into the delicate and significant work of the spectroscope. It is well worth while to form clear views on this point, because so many of the wonders of modern science are associated with spectroscopic analysis.

If, through a small round hole in a shutter, light is admitted into a darkened room, and a prism be placed with its refracting angle downwards and horizontal, a vertical spectrum, having its violet end uppermost, will be formed on a screen suitably placed to receive it.

But now let us consider what this spectrum really is. If we take the light-waves corresponding to any particular colour, we know from optical considerations, that these waves emerge from the prism in a pencil exactly resembling in shape the pencil of white light which falls on the prism. They therefore form a small circular or oval image on their own proper part of the spectrum. Hence the spectrum is in reality formed of a multitude of overlapping images, varying in colour from violet to red. It thus appears as a rainbow-tinted streak, presenting every gradation of colour between the utmost limits of visibility at the violet and red extremities.

If we had a square aperture to admit the light, we should get a similar result. If the aperture were oblong, there would still be overlapping images; but if the length of the oblong were horizontal, then, since each image would also be a horizontally-placed oblong, the overlapping would be less than when the images were square. Suppose we diminish the overlapping as much as possible; in other words, suppose we make the oblong slit as narrow as possible. Then, unless there were in reality an infinite number of images distributed all along the spectrum from top to bottom, the images might be so narrowed as not to overlap; in which case, of course, there would be horizontal dark spaces or gaps in our spectrum. Or again, if we failed in finding gaps of this sort by simply narrowing the aperture, we might lengthen the spectrum by increasing the refracting angle of the prism, or by using several prisms, and so on.

The first great discovery in solar physics, by means of the analysis of the prism (though the discovery had little meaning at the time), consisted in the recognition of the fact, that by means of such devices as the above, dark gaps or cross-lines *can* be seen in the solar spectrum. In other words, light-waves of the various gradations corresponding to all the tints of the spectrum from violet to red, do *not* travel to us from the great central luminary of our system. Remembering that the effect we call colour is due to the length of the light-waves, the effect of red corresponding to light-waves of the greatest length, while the effect of violet corresponds to the shortest light-waves, we see that in effect the sun sends forth to the worlds which circle around him light-waves of many different lengths, but not of all lengths. Of so complex and interesting a nature is ordinary daylight.

But spectroscopists sought to interpret these dark lines in the solar spectrum, and it was in carrying out this inquiry—which even to themselves seemed almost hopeless, and to many would appear an utter waste of time—that they lighted upon the noblest method of research yet revealed to man.

They examined the spectra of the light from incandescent substances (white-hot metals and the like), and found that in these spectra there are no dark lines.

They examined the spectra of the light from the stars, and found that these spectra are crossed by dark lines resembling those in the solar spectrum, but differently arranged.

They tried the spectra of glowing vapours, and they obtained a perplexing result. Instead of a number of dark lines across a rainbow-tinted streak, they found bright lines of various colour. Some gases would give a few such lines, others many, some only one or two.

Then they tried the spectrum of the electric spark, and they found here also a series of bright lines, but not always the same series. The spectrum varied according to the substances between which the spark was taken and the medium through which it passed.

Lastly, they found that the light from an incandescent solid or liquid, when shining through various vapours, no longer gives a spectrum without dark lines, but that the dark lines which then appear vary in position, according to the nature of the vapour through which the light has passed.

Here were a number of strange facts, seemingly too discordant and too perplexing to admit of being interpreted. Yet one discovery only was wanting to bring them all into unison.

In 1859, Kirchhoff, while engaged in observing the solar spectrum, lighted on the discovery that a certain double dark line, which had already been found to correspond exactly in position with the double bright line forming the spectrum of the glowing vapour of sodium, was intensified when the light of the sun was allowed to pass through that vapour. This at once suggested the idea, that the presence of this dark line (or rather, pair of dark lines) in the spectrum of the sun is due to the existence of the vapour of sodium in the solar atmosphere, and that this vapour has the power of absorbing the same order of light-waves as it emits. It would of course follow from this, that the other dark lines in the solar spectrum are due to the presence of other absorbent vapours in its atmosphere, and that the identity of these would admit of being established in the same way, supposing this general law to hold.

that a vapour emits the same light-waves that it is capable of absorbing.

Kirchhoff was soon able to confirm his views by a variety of experiments. The general principles to which his researches led—in other words, the principles which form the basis of spectrum analysis—are as follow:—

1. An incandescent solid or liquid gives a continuous spectrum.

2. A glowing vapour gives a spectrum of bright lines, each vapour having its own set of lines, so that from the appearance of a bright-line spectrum one can tell the nature of the vapour or vapours whose light forms the spectrum.

3. An incandescent solid or liquid shining through absorbent vapours gives a rainbow-tinted spectrum crossed by dark lines, these dark lines having the same position as the bright lines belonging to the spectra of the vapours; so that, from the arrangement of the dark lines in such a spectrum, one can tell the nature of the vapour or vapours which surround the source of light.*

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* To these may be added the following laws:—

4. Light reflected from any opaque body gives the same spectrum as it would have given before reflection.

5. But if the opaque body be surrounded by vapours, the dark lines corresponding to these vapours make their appearance in the spectrum with a distinctness proportioned to the extent to which the light has penetrated those vapours before being reflected to us.

6. If the reflecting body be itself luminous, the spectrum belonging to it is superadded to the spectrum belonging to the reflected light.

7. Glowing vapours surrounding an incandescent source of light

The application of the new method of research to the study of the solar spectrum quickly led to a number of most interesting discoveries. It was found that besides sodium the sun's atmosphere contains the vapours of iron, calcium, magnesium, chromium, and other metals. The dark lines corresponding to these elements appear unmistakably in the solar spectrum. There are other metals—such as copper and zinc, which seem to exist in the sun, though some of the corresponding dark lines have not yet been recognised. As yet it has not been proved that gold, silver, mercury, tin, lead, arsenic, antimony, or aluminium exist in the sun—though we can by no means conclude, nor indeed is it at all probable, that they are absent from his substance. The dark lines belonging to hydrogen are very well marked indeed in the solar spectrum, and, as we shall see presently, the study of these lines has afforded most interesting information respecting the physical constitution of the sun.

Now, we notice at once how importantly these researches into the sun's structure bear upon the sub-

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may cause bright lines or dark lines to appear in the spectrum, according as they are more or less heated; or they may emit just so much light as to make up for what they absorb, in which case there will remain no trace of their presence.

8. The electric spark presents a bright-line spectrum, compounded of the spectra belonging to the vapours of those substances between which, and of those through which, the discharge takes place. According to the nature of these vapours and of the discharge itself, the relative intensity of the component parts of the spectrum will be variable.

Lastly, the appearance of the spectrum belonging to any element will vary according to the circumstances of pressure and temperature under which the element may emit light.

ject of this treatise. It would be indeed interesting to consider the actual condition of the central orb of the planetary scheme, to picture in imagination the metallic oceans which exist upon his surface, the continual evaporation from those oceans, the formation of metallic clouds, and the downpour of metallic showers upon the surface of the sun. But apart from such considerations, and viewing Kirchhoff's discoveries simply in their relation to the subject of other worlds, we have enough to occupy our attention.

If it could have been shown that, in all probability, the substance of the sun consists of materials wholly different from those which exist in this earth, the conclusion obviously to be drawn from such a discovery would be that the other planets also are differently constituted. We could not find any just reason for believing that in Jupiter or Mars there exist the elements with which we are acquainted, when we found that even the central orb of the planetary system exhibits no such feature of resemblance to the earth. But now that we know quite certainly, that the familiar elements iron, sodium, and calcium exist in the sun's substance, while we are led to believe with almost perfect assurance, that all the elements we are acquainted with also exist there, we see at once, that in all probability the other planets are constituted in the same way. There may of course be special differences. In one planet the proportionate distribution of the elements may differ, and even differ very markedly from that which prevails in some other planet.

But the general conclusion remains, that the planets are formed of the elements which have so long been known as terrestrial; for we cannot recognise any reason for believing that our earth alone, of all the orbs which circle around the sun, resembles that great central orb in general constitution.*

Now, we have in this general law a means of passing beyond the bounds of the solar system, and forming no indistinct conceptions as to the existence and character of worlds circling around other suns. For it will be seen in the chapter on the stars, that these orbs, like our sun, contain in their substance many of the so-called terrestrial elements, while it may not unsafely be asserted that all or nearly all those elements, and few or no elements unknown to us, exist in the substance of every single star that shines upon us from the celestial concave. Hence we conclude, that around those suns also there circle orbs constituted like themselves, and therefore containing the elements with which we are familiar. And the mind is immediately led to speculate on the uses which those elements are intended to subserve. If iron, for example, is present in some noble orb circling around Sirius, we speculate not unreasonably respecting the existence on that orb —either now, or in the past, or at some future time— of being capable of applying that metal to the useful purposes which man makes it subserve. The imagination suggests immediately the existence of arts and sciences, trades and manufactures, on that distant world. We know how intimately the use of iron has been associated with the progress of human civilisation, and though we must ever remain in ignorance of the actual condition of intelligent beings in other worlds, we are yet led, by the mere presence of an element which is so closely related to the wants of man, to believe with a new confidence, that for such beings those worlds must in truth have been fashioned.

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* It will be seen, in the chapter on 'Meteors and Comets,' that this conclusion has a most important bearing on the views we are to form respecting the original formation of the planetary scheme.

I would fain dwell longer on the thoughts suggested by the researches of Kirchhoff. Gladly too would I enter at length on an account of those interesting discoveries which have been made in connection with the last three total eclipses of the sun. The requirements of space, however, and some doubt as to the direct bearing of the last-named discoveries on the subject I have in hand, warn me to forbear. One point, however, remains, which is too intimately connected with my subject to be passed over.

I refer to the sun's corona.

It has been proved that the solar prominences consist of glowing vapours, hydrogen being their chief constituent. It has been found also, by comparing observations of the prominence-spectra with elaborate researches into the peculiarities presented by the spectrum of hydrogen at different pressures, that even in the very neighbourhood of the solar photosphere, these vapours probably exist at a pressure so moderate as to indicate that the limits of the sun's vaporous envelope cannot lie very far (relatively) from the outer solar cloud-layer.

Now the solar corona has been seen, during total eclipses of the sun, to extend to a distance at least equal to the sun's diameter from the eclipsed orb. So that, assuming the corona to be a solar atmosphere, it would have a depth of about 850,000 miles, and being also drawn towards the sun by his enormous attractive energy (exceeding more than twenty-seven times that of the earth), it could not fail to exert a pressure on his surface exceeding many thousand-fold that of our air upon the earth. In fact, such an atmosphere, let its outermost layers be as rare as we can conceive, would yet have its lower layers absolutely liquefied, if not solidified by the enormous pressure to which they would be subjected. We cannot then believe this corona to be a solar atmosphere.

Yet it is quite impossible to dissociate the corona from the sun. Until 1872, some attempted to do this, and not only so, but to make of the zodiacal light a terrestrial phenomenon. But they had overlooked considerations which oppose themselves irresistibly to such a conclusion; and since the observation of the solar eclipse of December 1871, astronomers are of one accord in regarding the corona as appertaining to the sun.

But the spectroscope has given certain very perplexing evidence respecting the light of the corona, and it remains that we should endeavour to see how that evidence bears on the interesting problem which the corona presents to our consideration.

During the total eclipse of August 1869 the American observers found that the spectrum of the corona is continuous, but crossed by certain bright lines. If we accept the absence of dark lines as established by the evidence (which is doubtful), this result seems at first sight very difficult to explain. Referring to the principles of spectroscopic analysis stated at pp. 38, 39, it will be seen that we should be led to infer that the corona consists of incandescent matter surrounded by certain glowing gases. It is difficult to suppose that this is the real explanation of the phenomenon.

Now, remembering that we have two established facts for our guidance—(i.) the fact that the outer corona cannot be a solar atmosphere, and (ii.) the fact that it must be a solar appendage—I think a way may be found towards a satisfactory explanation.

Let it be premised that the bright lines of the coronal spectrum correspond in position, though not in brightness, to those seen in the spectrum of the aurora, and that the same lines are seen in the spectrum of the zodiacal light, and in that of the phosphorescent light occasionally seen over the heavens at night.

Since we have every reason to believe that the light of the aurora is due to electrical discharges taking place in the upper regions of the air, we are invited to the belief that the coronal light may be due to similar discharges taking place between the particles (of whatever nature) constituting the corona.

Now, though the appearance of an aurora is due to some special terrestrial action (however excited), yet the material substances between which the discharges take place must be assumed to be at all times present in the upper regions of air. In all probability, they are the particles of those meteors which the earth is continually encountering. And since we know that meteor systems must be aggregated in far greater numbers near the sun than near the earth, we may regard the coronal light as due to electrical discharges excited by the sun's action, and taking place between the members of such systems. Besides this light, however, there must necessarily be a large proportion of light reflected from these meteoric bodies. In this way the peculiar character of the coronal spectrum may be readily accounted for. We know from the auroral spectrum, that the principal bright lines due to the electrical discharges would be precisely where we see bright lines in the coronal spectrum. But, besides these, there would be fainter bright lines corresponding to the various elements which exist in the meteoric masses. These elements, we know, are the same as those in the substance of the sun. Thus, the bright lines would correspond in position with the dark lines of the solar spectrum. Hence, as light reflected by the meteors would give the ordinary solar spectrum, there would result from the combination a continuous spectrum, on which the bright lines first mentioned would be seen, as during the American eclipse.

What the polariscope has told us respecting the corona is in accordance with this view.

In the same way the quality of the zodiacal light admits of being perfectly accounted for, without resorting to the hypothesis that this phenomenon is a terrestrial one.

The explanation thus put forward has at least the advantage of being founded on well-established relations. We know that the auroral light is associated with the earth's magnetism, and that meteoric bodies are continually falling upon the earth's atmosphere. We know also, that the sun exerts magnetic influences a thousand-fold more intense than those of the earth, and that in his neighbourhood there must be many million times more meteoric systems.

But we have other and independent reasons which must not be overlooked, for considering the corona to be of some such nature as I have suggested.

Leverrier has shown that there probably exists in the neighbourhood of the sun a family of bodies whose united mass suffices appreciably to affect the motions of the planet Mercury. It would not be safe to neglect considerations thus vouched for.

Mr. Baxendell, also, has shown that certain periodic variations in the earth's magnetism point to the existence of such a family of bodies; and he has been able to assign to them a position according well with that determined by Leverrier.

Now, whatever opinion we form as to the exact character of the system of bodies pointed to by the researches of Leverrier and Baxendell—whether we suppose that system to form a zone around the sun, or that (as I believe) the system is merely due to the aggregation of meteoric perihelia in the sun's neighbourhood—we may be quite certain that during a total solar eclipse the system would become visible.

In the eclipse of December 1871 striking evidence was obtained respecting the corona. For Janssen was able to perceive the solar dark lines in the spectrum of the corona—proof unmistakable that a portion of the coronal light is reflected sunlight. It had been a difficulty in the meteoric theory that these solar lines had not been detected in the faint continuous spectrum of the corona. The meteoric theory, that is the theory that a portion of the coronal light is due to light-reflecting meteors round the sun, accorded with all the known phenomena of the corona except this single peculiarity, that (as was supposed) the spectrum showed no dark lines. Now that the dark lines have been seen, all doubt seems finally removed. As Janssen said in the letter containing the discovery, 'the atmospheric theory is disposed of (*tranchée*), and we must recognise in the corona a circumsolar phenomenon containing effects of radiation, absorption, and reflection of light,' which it must be the business of future eclipse observers to analyse in detail.

During the eclipse of July 1878, the corona was found to extend to at least seven or eight millions of miles from the body of the sun.

It will be seen, in the chapter on 'Meteors and

Comets,' how important a bearing the meteoric theory of the corona (that is, of a portion of its light) has upon the history of the solar system. It has been partly for this reason that I have here briefly considered the matter; but there is another and a most important relation in which these views must be regarded.

We know that the sun is the sole source whence light and heat are plentifully supplied to the worlds which circle around him. The question immediately suggests itself—Whence does the sun derive those amazing stores of force from whence he is continually supplying his dependent worlds? We know, that were the sun a mass of burning matter, he would be consumed in a few thousand years. We know, that were he simply a heated body, radiating light and heat continually into space, he would in like manner have exhausted all his energies in a few thousand years—a mere day in the history of his system. Whence, then, comes the enormous supply of force which he has afforded for millions on millions of years, and which also our reason tells us he will continue to afford while the worlds which circle around him have need of it—in other words, for countless ages yet to come?

Now there are two ways in which the solar energies might be maintained. The mere contraction of the solar substance, Helmholtz tells us, would suffice to supply such enormous quantities of heat, that if the heat actually given out by the sun were due to this cause alone, there would not, in many thousands of years, be any perceptible diminution of the sun's diameter. Secondly, the continual downfall of meteors upon the sun would cause an emission of heat. But though the sun's increase of mass from this cause would not be rendered perceptible in thousands of years, either by any change in his apparent size or by changes in the motions of his family of worlds, yet the supply of heat obtainable in this way can be but small compared with the sun's emission of heat. This follows from the limits between which Leverrier has shown that the total mass of the meteors of our system must certainly lie.*

It seems far from unlikely that both these processes are in operation at the same time. Certainly the latter is, for we know, from the motions of the meteoric bodies which reach the earth, that myriads of these bodies must continually fall upon the sun. If the corona and zodiacal light are really due to the existence of flights of meteoric systems circling around the sun, or to the existence in his neighbourhood of the perihelia of many meteoric systems, then there must be a supply of light and heat from this source, though not nearly sufficient to account for the solar emission.

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* Undue stress has been laid upon the probable change in the length of the year, owing to the downfall of meteors upon the sun's mass. It is forgotten that the crowded meteors forming the solar corona are *already* within the earth's orbit, and therefore already produce their full effect on the length of the year. The subsidence of all these bodies at once upon the sun would not affect the length of the year, though it would lead to certain modifications in the secular perturbations of the earth's orbit in figure and position.

It is well worthy of notice, however, that the association between meteors and comets has an important bearing on this question. We know that the most remarkable characteristic of comets is the enormous diffusion of their substance. Now in this diffusion there resides an enormous fund of force. The contraction of a large comet to dimensions corresponding to a very moderate mean density would be accompanied by the emission of a vast supply of heat. The question is worth inquiring into, whether we can indeed assume that the meteors which reach our atmosphere are solid bodies, and not rather of cometic diffusion; since it is difficult otherwise to account for the light and heat which they emit. Friction through the rarer upper strata of our atmosphere will certainly not account for these phenomena; nor, I think, will the compression of the atmosphere in front of the meteors: on the other hand, the sudden contraction of a diffused vapour would be accompanied by precisely such results. But, be this as it may, it is certain that a large portion of the substance of every comet is in a singularly diffused state. Since the meteoric systems circling in countless millions round the sun are, in all probability, associated in the most intimate manner with comets, we may recognise in this diffusion, as well as in the mere downfall of meteors, the source of an enormous supply of light and heat.

Lastly, turning from our sun to the other suns which shine in uncounted myriads throughout space, we see the same processes at work upon them all.

Each star-sun has its coronal and its zodiacal discs, formed by meteoric and cometic systems; for otherwise each would quickly cease to be a sun. Each star-sun emits, no doubt, the same magnetic influences which give to the zodiacal light and to the solar corona their peculiar characteristics. Thus the worlds which circle round those orbs may resemble our own in all those relations which we refer to terrestrial magnetism, as well as in the circumstance that on them also there must be, as on our own earth, a continual downfall of minute meteors. In those worlds, perchance, the magnetic compass directs the traveller over desert wastes or trackless oceans; in their skies, the aurora displays its brilliant streamers; while, amid the constellations which deck their heavens, meteors sweep suddenly into view, and comets extend their vast length athwart the celestial vault, a terror to millions, but a subject of study and research to the thoughtful.

CHAPTER III.

THE INFERIOR PLANETS.

IN considering the habitability of various portions of the solar system, we have to draw a marked distinction between the planets which travel within the orbit of the earth, and those which lie beyond its range. So far, indeed, as our belief in these orbs being inhabited is concerned, we may apply the same processes of reasoning to one set of planets as to the other. Until it has been demonstrated that no form of life can exist upon a planet, the presumption must be that the planet is inhabited. But it is impossible to contemplate the various members of our solar system, without being led to consider their physical habitudes rather with relation to the wants of such creatures as exist upon our own earth than merely with reference to the existence of life of some sort upon their surface. Viewing Venus and Mercury in this way, we have a different set of relations to deal with than we find among the outer planets. We are struck, at once, with the marked effects which seem associable with their comparative proximity to the sun's orb. This feature and the shortness of their period of revolution—that is, of their year, are the characteristic peculiarities we have to deal with.

I would willingly pay some attention here to the story of Vulcan, the planet which has been supposed to circle yet more closely than Mercury around the centre of our system, were it not for the great doubt in which the existence of this planet seems enshrouded.

Mercury circles around the sun in the brief period of eighty-eight days, or rather less than three of our months. So that, if the planet has seasons, these must be severally about three weeks long. His distance from the sun varies between somewhat wide limits, owing to the eccentricity of his orbit. When he is nearest to the sun, he receives ten and a half times more light and heat from that luminary than we do; but when he removes to his greatest distance, the light and heat he receives are reduced by more than one-half. Even then, however, the sun blazes in the skies of Mercury with a disc four and a half times larger than that which he presents to the observer on earth.

Undoubtedly these peculiarities, the shortness of the Mercurial year, and the immense amount of light and heat poured by the sun upon the planet, are circumstances which do not encourage, at first sight, the belief that any creatures can subsist upon this planet resembling those with which we are familiar. We see, at once, that all forms of vegetation in Mercury must differ in a very striking manner from those which exist upon the earth, because their structure has to be adapted to much more rapid changes of temperature.

And the existence of a totally distinct flora suggests at once the belief that animal life on Mercury must be very different from what we see around us.

Let us, however, proceed a few steps farther.

It has been found that Mercury rotates upon his axis, and if we may put faith in the observations of Schröter, the Mercurial day is only a few minutes longer than our own. But though the fact of the planet's rotation has been observed, it has not been found possible to determine in what position the axis of rotation lies. It has been said that the planet's equator is much more inclined than the earth's to the plane in which the planet travels; but little reliance can be placed on the evidence which has been adduced in favour of this view.

We are thus left altogether in doubt as to the nature of the Mercurial seasons. That the planet has seasons of some sort we are certain, because even if the axis were so placed that perpetual spring reigned upon the planet—I mean, that the days and nights were at all times and in all places equal—yet his varying distance from the sun would give changes of temperature quite as marked as those which characterise our seasons in England, and very much more marked than those known in tropical regions. Of course, if this is the actual arrangement, there are different climates in different parts of the planet. Near his poles, the sun, though visible for half the Mercurial day, attains yet but a low elevation above the horizon; just as he does on a spring day within our own polar circles. At the equator the sun passes day after day to the zenith, and pours down upon the planet an amount of light and heat far exceeding the light and heat of our tropical climates. A sun immediately overhead, and showing a diameter varying from more than twice to more than three times that of our sun, must be a noble and may be a terrible phenomenon in the skies of Mercury.

There is yet another arrangement by which, to a portion of the planet, at any rate, the Mercurial seasons might be tempered. If his axis is so placed that what would be the winter season were his orbit not eccentric, takes place, for one hemisphere, when the planet is nearest to the sun, then undoubtedly it may very well happen (the inclination of his axis being suitably adjusted) that this so-called winter season is the warmest part of the year for that hemisphere. In this case, there would be the least possible violence in the succession of the Mercurial seasons for that hemisphere. But in the other hemisphere the seasonal changes would be correspondingly intensified.

In either of these cases, it is readily conceivable that even forms of life resembling those we are acquainted with on earth might exist on Mercury, and this without any special provision for tempering the great heat and light of the sun. Those regions which correspond to our temperate and tropical zones would indeed scarcely be habitable; but the polar regions of the planet would not form a disagreeable abode.

If, however, the equator of the planet is very much inclined to the plane in which Mercury travels, it cannot be doubted that no form of life known upon earth can possibly exist upon Mercury, *without* some special arrangements for tempering the seasonal changes. This will appear when we come to deal with the effect of the great inclination which some astronomers have ascribed to the equator of Venus; and therefore we need not consider the relation with regard to Mercury, respecting whose axial inclination no trustworthy information has hitherto been obtained.

It remains for us to consider what sort of provision may have been made to temper the great heat poured by the sun upon Mercury.

The climate of a planet, considered generally, is largely influenced by the nature of the planet's atmosphere. We have very clear evidence on this point, in the effects which we notice on our own earth. If we ascend to the summit of a lofty mountain, we find the air much colder than at its base. In India, though the full heat of a tropical sun is poured day after day upon the snowy summits of the Himalayas, yet the air continues colder than in the bitterest midwinter weather experienced by us in England. Not that the solar rays have no power. The heat is, in reality, even greater than on the plains, because it has not been intercepted by vapour-laden air. But the air itself is not heated. Owing to its extreme rarity and dryness, it neither impedes the passage of the sun's heat to the earth, nor prevents the return of that heat from the earth by radiation or reflection; and this very fact, that it does not impede the passage of heat, means nothing else than that the air does not become heated.*

We have, then, so far as a rare atmosphere is concerned, two points to dwell upon—the readiness with which such an atmosphere permits the sun's heat to reach the surface of a planet, and the readiness with which it permits the planet's heat to pass away into space. Now we might feel doubtful which of these two effects was chiefly to be regarded, were it not that on our own earth we have experience of the effects of a very rare atmosphere. We know that the climate of very elevated regions is relatively much cooler than that of places on the plain. Thus we learn that the direct heating powers of the sun are not so much to be considered, in judging of the climate of any region, as the quality of the atmosphere.

Yet we must not deceive ourselves by inferring that mere rarity of atmosphere can compensate fully for an increased intensity of solar heat. It is not true that the climate of a place on the slopes of the Andes or the Himalayas corresponds to that of a region on the plain which has an atmosphere equally warm. The circumstances are, in fact, wholly different. On the plain there is, it is true, the same amount of heat in the case supposed; but the air is denser and more moisture-laden: the nights are warmer because the skies are less clear and the heat escaping from the earth is intercepted by clouds or by the transparent aqueous vapour in the air; and lastly, there is not so great a contrast between the warmth of the air and the direct heat of the solar rays.

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* The following passage, quoted by Prof. Tyndall from Hooker's 'Himalayan Journals,' illustrates the peculiarities referred to above:—'At 10,000 feet, in December, at 9 A.M., I saw the mercury mount to 132°, while the temperature of shaded snow hardly was 22°. At 13,100 feet, in January, at 9 A.M., it has stood at 98°, with a difference of 68·2°, and at 10 A.M., at 114°, with a difference of 81·40°, whilst the radiating thermometer on the snow had fallen at sunrise to 0·7°.' Such observations as these are well worth studying. It is interesting to consider that at the summit of the highest peaks of the Himalayas the mid-day heat due to the sun must sometimes be near if not above the boiling point corresponding to those places, since water would boil on Mount Everest at a temperature of little more than 160°.

If the atmosphere of Mercury, therefore, be excessively rare, as some have supposed, so as to afford an Alpine or Himalayan climate in comparison with the tremendous heat we should otherwise ascribe to the climate of the planet, there would by no means result a state of things resembling that with which we are familiar on earth. We must not, in our anxiety to people Mercury with creatures such as we know of, blind ourselves to the difficulties which have to be encountered. We cannot thin the Mercurial air, without adding to the direct effects of the sun upon the Mercurial inhabitants. Whether in this way we increase the habitability of the planet may be doubted, when we consider that the direct action of the sun's rays upon the tropical regions of Mercury, thus deprived of atmospheric protection, would produce a heat four or five times greater than that of boiling water. It will hardly be thought that the intense cold in the shade, or during the Mercurial night, would compensate for so terrible a heat. In fact, this view of the Mercurial climate would lead us to find a close resemblance between the inhabitants of the planet and the unfortunates described by Dante as doomed

> A sofferir tormenti e caldi e gieli.

It would seem hard to believe in the existence of any organised forms under such conditions, unless perhaps such 'microscopic creatures, with siliceous coverings' as Whewell proposed to people Venus with.

However, we have yet to consider whether an atmosphere of a different sort might not be better suited to the requirements of Mercury. We have seen the effects of a rare atmosphere, let us inquire into those which might be ascribed to a dense one.

The ordinary effect of a dense atmosphere we know to be an increase of heat, which is certainly not what we require in the case of Mercury. Nor are we familiar with any region upon our earth in which a dense atmosphere produces a contrary *climatic* effect; so that we have no analogy to support us in the belief, that possibly a dense atmosphere might, under particular circumstances, serve to guard a planet from the solar rays. It seems possible, however, that an atmosphere might be so constituted as to remain almost constantly loaded with heavy cloud-masses. In this case, it by no means follows that such effects would follow as we ordinarily associate with a moisture-laden atmosphere. Up to a certain point, doubtless, the increase of moisture in the air tends to an increase of warmth; because the aqueous vapour exercises a greater effect in preventing the escape of heat from the earth than in guarding the earth from the solar rays. And as I have said, the only *climatic* effect we can associate with the frequent presence of large quantities of aqueous vapour in the air, or therefore with an ordinarily clouded state of the sky, is that of a general increase of heat. But, just as we know that a cloudy day is not necessarily nor even commonly a warm day; it may well be that an atmosphere so dense as to be at all times cloud-laden, serves as a protection from the sun's intense heat. So that, instead of assigning dense atmospheres exclusively to the more distant planets, as some astronomers have done, we might be led to see in an envelope of great density the means of defending the inhabitants of Mercury and Venus from the otherwise unendurable rays of their near neighbour the sun.

Although Mercury is not a planet which can be satisfactorily examined with the telescope, yet, so far as can be judged from his aspect, his atmosphere is in reality much denser than our earth's, and loaded with cloud-masses of enormous extent. Still the evidence on these points is far from satisfactory; and there is one peculiarity of the planet which does not accord with this view of the constitution of his atmosphere. Undoubtedly, if the light we receive from Mercury came from a cloudy envelope, it would be more brilliant than the light we should receive from the surface of continents and oceans. In fact, the most brilliant light we could receive from a globe of a given size, placed at a given distance from the sun, would be that which would be reflected were such a globe covered with clouds. Now there can be no doubt whatever, that Mercury does not reflect the same proportion of light from his surface that some of the planets do. He would be, when favourably situated, the brightest of all the planets, were this so;* though, seen as he always is, on the bright background of a full twilight sky, he would not make so striking an appearance as Jupiter does when in opposition. This, however, is not the case. I remember being much struck by the superior light of Jupiter, on the afternoon of February 23, 1868, when the two planets were very close together, Mercury being nearly at his brightest, whereas Jupiter, then near conjunction, was considerably less

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* Placing Mercury in perihelion and at his elongation, we get a half disc, the planet about 90,000,000 miles from us, and about 30,000,000 from the sun, his diameter about 3,000 miles. Now, if we wish to compare the light he then sends us with that of Jupiter at his brightest, on the assumption of equal reflective powers, we must take Jupiter at a distance of about 360,000,000 miles from us, and about 450,000,000 miles from the sun, showing a full disc, his diameter about 90,000 miles (I put all the numbers *round*, for convenience of calculation). We find, then, that the ratio of Mercury's light to Jupiter's is

$$\frac{1}{2}\,\frac{(3.000)^2}{(90,000,000)^2 \times (30,000,000)^2} : \frac{(90,000)^2}{(360,000,000)^2 \times (450,000,000)^2}$$

or $\frac{1}{2}\,(4)^2(15)^2 : (30)^2$, or exactly 2 to 1.

The observation above cited is sufficient to prove that a very different state of things actually prevails; in other words, that the reflective powers of the two planets are very different: unless, indeed, Jupiter shines in part by inherent light.

bright than when in opposition. Venus was close by, and outshone both Mercury and Jupiter.

It seems difficult, therefore, to believe that the light of Mercury comes from a cloudy envelope. But there is still one supposition which may restore our belief in the habitability of the planet by creatures not very different from those which inhabit our earth. If it has a double cloud envelope, the upper like our cirrus clouds, less compact than the lower, and permitting a portion of the sunlight to pass through, it is possible that the lower cloud-layer would be seen partly in shadow. I must admit that the explanation is not quite satisfactory, because, just as much light as the outer clouds intercepted they would reflect; still, it is conceivable, that the usual arrangement of these clouds may be such, that to us, who do not look at the planet in the direction in which the sun's rays fall, but somewhat aslant, the shadows of the upper clouds upon the dense and compact lower envelope may be rendered in large part visible.

After all, the reader may prefer the view which recognises in the polar regions of Mercury places suitable for organic existences, while the equatorial and neighbouring regions are zones of fire, whose dangers the bravest Mercurials, the very Livingstones upon that planet, would not dare to face. We may picture to ourselves, on this view, the various contrivances by which the inhabitants of the two polar (that is, in reality, temperate) circles manage to communicate. There may be regions where favouring circumstances narrow the uninhabitable zone so much that the inhabitants of one polar circle may travel to the other (or, at least, cross the most dangerous portion of the hot zone) in the course of the Mercurial night. Or perhaps tunnels may be run, or sheltered cuttings made, along which the voyage may be made in comparative safety. Ocean communications there can be none, if the Mercurial skies are clear, since the sun's heat on the tropical zone would suffice to boil away any water which might find its way there.

Certainly, the smallness of the planet and the diminished effects of gravity upon its surface, would tend to make communication much easier, and the construction of protective tunnels or cuttings a comparatively light task. What the exact force of gravity at the surface of Mercury may be we do not know, because our means of determining the mass of the planet are not so satisfactory as in the case of the other primary members of the solar system. If Mercury had a satellite, we could tell his weight at once. If he were as large as Venus, we could tell his weight by observing his effect in disturbing the motions of that planet. As it is, the only means we have of weighing Mercury is the observation of his effect in disturbing any comet which may pass near him. In this way the planet has been weighed, but the balance thus employed is not a satisfactory one altogether, because we are not quite certain how much of the disturbance of a comet when near Mercury is due to the planet's attraction. Formerly, it was supposed that the mean density of Mercury is equal to that of lead; but from the perturbations of Encke's comet in Mercury's neighbourhood, astronomers have been led to the conclusion that the density of the planet is not more than one-sixth greater than our earth's. It follows, that as his diameter is little more than 3,000 miles, our earth is about fifteen times as heavy as Mercury. Gravity at his surface is such, that a pound weight of ours would weigh rather less than seven ounces of Mercury. Hence the creatures which seem to us most unwieldy—the elephant, the hippopotamus, and the rhinoceros, or even those vast monsters, the mammoth, the mastodon, and the megatherium, which bore sway over our globe in far-off eras—might emulate on Mercury the agility of the antelope or the greyhound.

There can be no doubt that where gravity acts so feebly, all engineering operations would be rendered very much simpler—bridges could have a wider span, and yet be stronger than our terrestrial ones, buildings could be loftier and yet be raised more easily, and transit of all sorts would be effected much more readily, while at the same time the distances to be traversed are very much less than on our earth, since the surface of Mercury is little more than one-seventh of the earth's.

The peculiarities which characterise Venus are for the most part similar in kind to those we have had to consider in the case of Mercury. But at the outset of our inquiries into the physical habitudes of this most beautiful planet, we must point to the striking resemblance which it bears, in some respects, to our own earth. So far, indeed, as telescopic and physical researches have yet led us, the planet Mars, as we shall presently see, appears to exhibit habitudes more closely corresponding to those we are apt to consider essential to the wants of living creatures. But in size, in situation, and in density, in the length of her seasons and of her rotation, in the figure of her orbit and in the amount of light and heat she receives from the sun, Venus bears a more striking resemblance to the earth than any orb within the solar system. In fact, there is no other pair of planets between which so many analogies can be traced as between Venus and the earth. Uranus and Neptune are similar in many respects, but they differ in at least as many. Jupiter and Saturn are, in a sense, the brother giants of the solar scheme, while the dwarf orbs Mars and Mercury present many striking points of similarity; but between neither of these pairs can we trace so many features of resemblance as those which characterise the twin planets Venus and Terra, while the features of dissimilarity in either pair are perhaps even more obvious than the points of resemblance. Had Venus but a moon as the earth has, we might doubt whether, in the whole universe, two orbs exist which are so strikingly similar to each other.

And here we may pause for a moment to consider one of the most perplexing enigmas that has ever been presented to astronomers. Are we indeed certain that Venus has no moon? The question seems a strange one, when it is remembered that year after year Venus